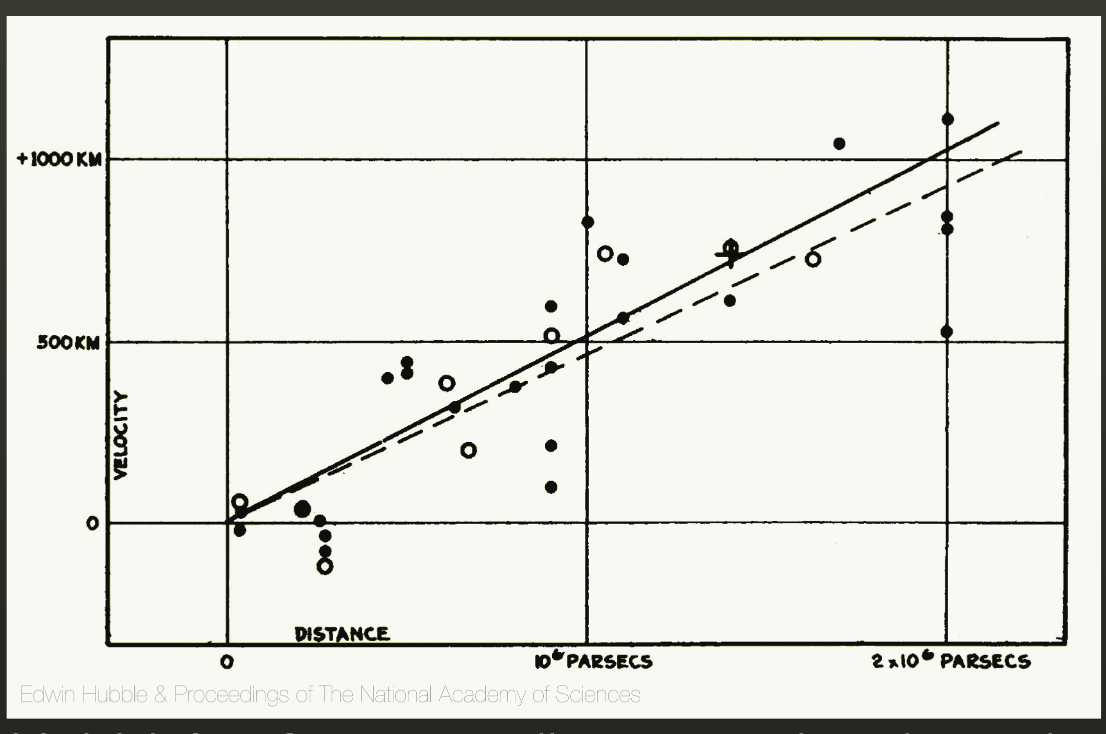
Our Universe Began with a Bang

Edwin Hubble

Throughout the Universe, galaxies are rushing away from us – and from each other – at tremendously high speeds. This fact tells us that the Universe is expanding over time. Edwin Hubble (after whom the Hubble Space Telescope was named) first measured the expansion in 1929.



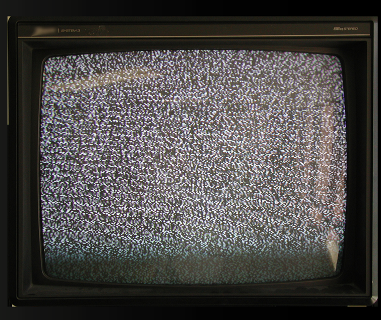
Hubble's famous diagram showing the distance versus velocity of the galaxies he observed. The farther away the galaxies, the faster they are moving, showing that the Universe is expanding.

This posed a big question. If we could run the cosmic movie backward in time, would everything in the Universe be crammed together in a blazing fireball – the starting point of the Big Bang? A lot of scientific debate and many new theories followed Hubble's discovery.

Among those in the front lines of the debate were physicists Ralph Alpher and Robert Herman. In 1948 they predicted that an afterglow of this fireball should still exist, though at a much lower temperature than at the time of the Big Bang.

Here's why: As the Universe expands, the waves of heat radiation from the Big Bang are stretched out, and cool from visible energy to infrared and then to microwave wavelengths. Microwaves are just short-wavelength radio waves, the same form of energy used in microwave ovens.

Fun Fact: About 1% of the "snow" you see on broadcast TV is caused by the cosmic microwave background.



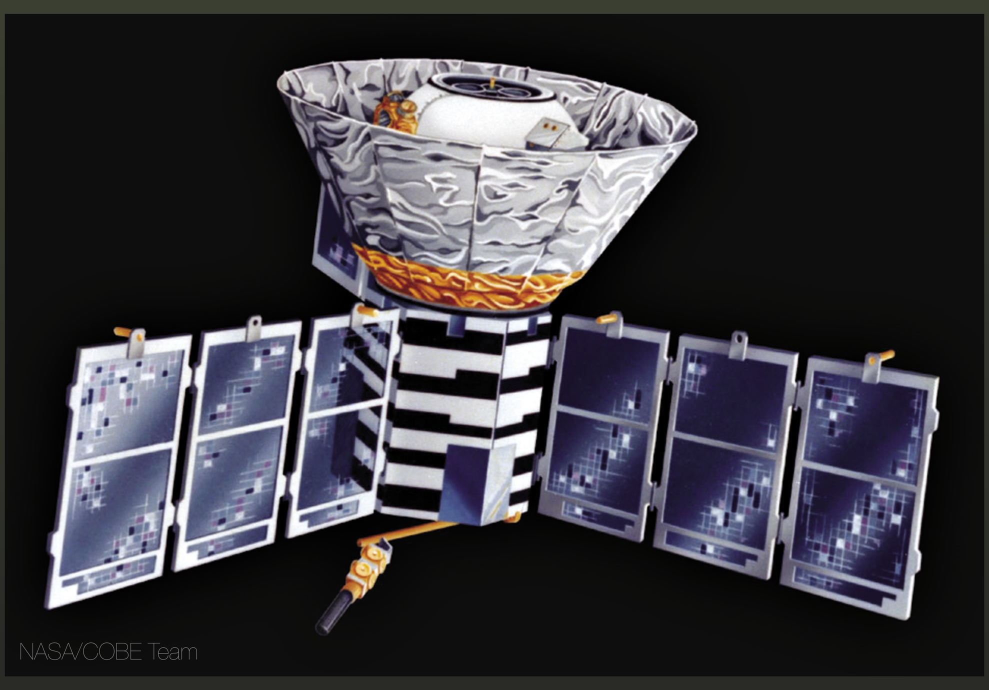
The prediction of an afterglow could be tested! Scientists began building instruments to detect this "cosmic microwave background", or CMB.

Wilson and Penzias used this radio receiver in their accidental discovery of the Cosmic Microwave Background.

In 1964, radio engineers Arno Penzias and Robert Wilson detected the afterglow – accidentally. While making microwave observations of the sky in the New Jersey countryside, they found they were unable to eliminate a background hiss in their receivers. This "noise" turned out to be the CMB, one of the most significant discoveries of our time.

The Oldest Baby Picture

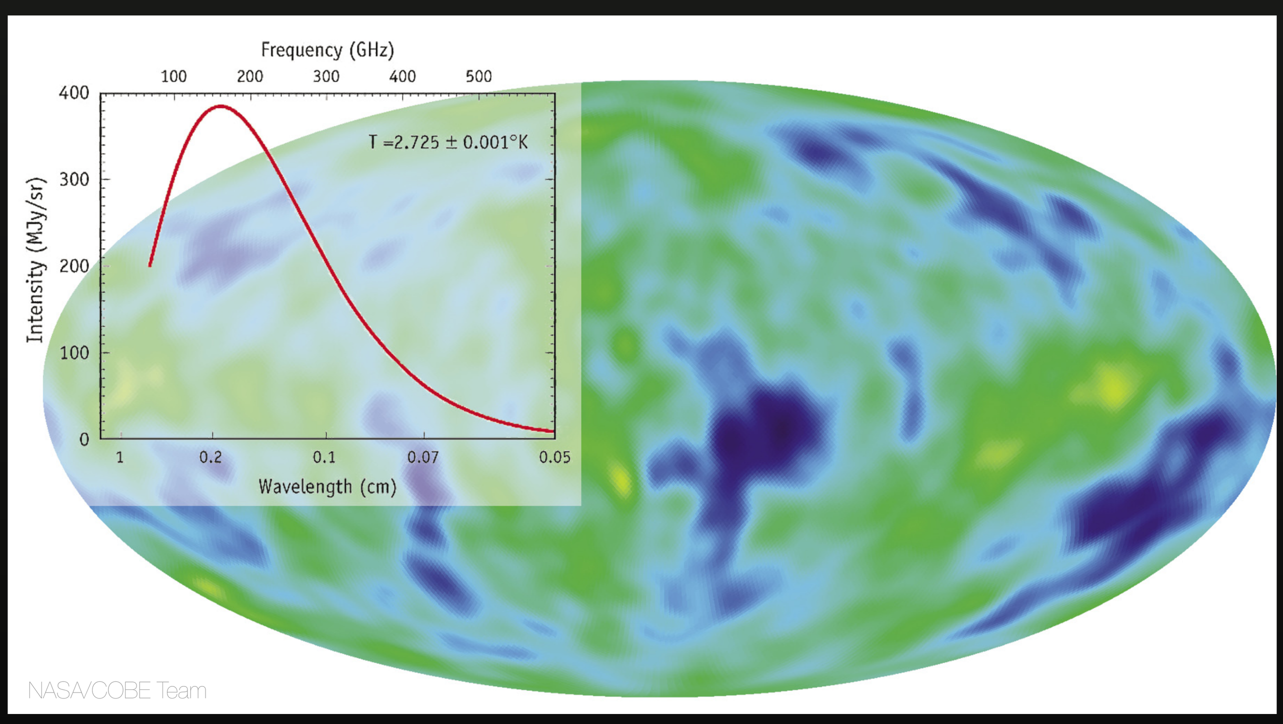
The cosmic microwave background radiation (CMB) is a remnant of the early Universe, and it fills all of space. Taking its temperature in all different directions is a powerful way to study the history of our 13.7 billion year old Universe. Studying the CMB takes us back to only 380,000 years after the Big Bang, and gives us a "baby picture" of the Universe.



The Goddard-built COBE satellite.

Goddard scientists and their collaborators designed, built, and then launched in 1989 the very first satellite dedicated to studying the CMB. Data from this Cosmic Background Explorer (COBE) perfectly matched only one scientific theory about the beginning of the Universe: the Big Bang. All other theories were eliminated.

COBE allowed scientists to determine that the average temperature of the CMB is an amazing 2.73 Kelvin (-454.76 degrees Fahrenheit), barely above absolute zero, which is the coldest temperature possible. Later data revealed that the CMB was denser in some directions than others, but only by one part in 100,000! These very slight patchy differences in the density revealed that matter in the early Universe was not evenly distributed.



Two important COBE results are the temperature of the Cosmic Microwave Background (defined by the curve in the upper left) and the uneven distribution of matter in the early universe (demonstrated by slight temperature differences in the oval projection of the sky).

If the early Universe had been perfectly uniform, we wouldn't be here. More matter means more gravity, so gas clouds began to clump together in the areas of greater density. The wheels were in motion, and those clumps eventually became the structures we know today – galaxies, stars, planets, and the immense voids between them.

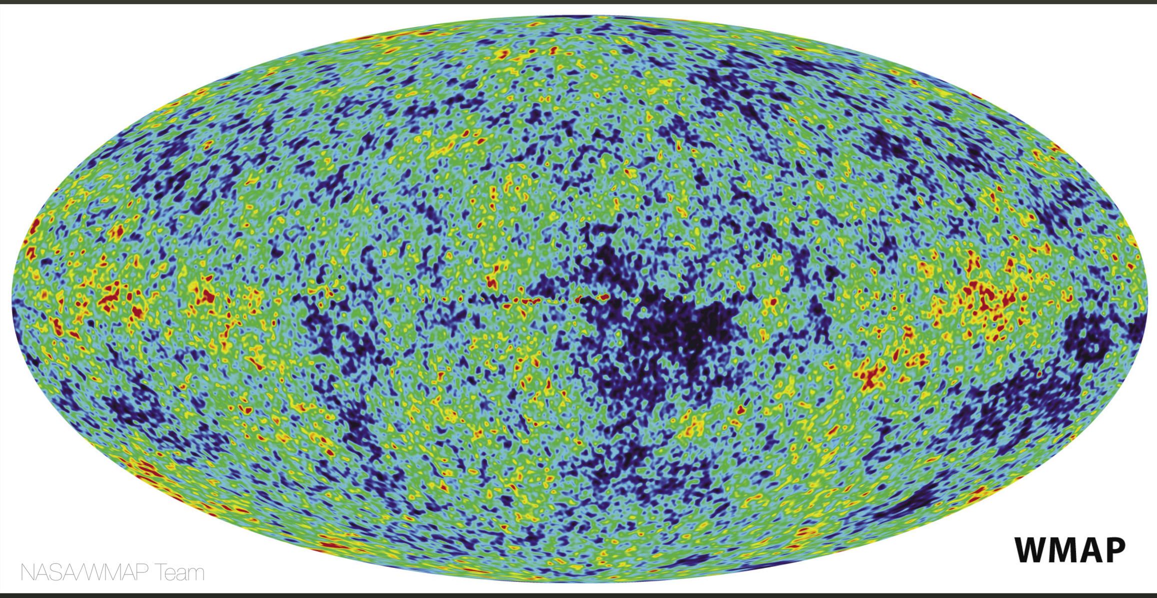
John Mather (at left) receives the 2006 Nobel Prize in physics for his CMB discoveries from the COBE mission.

These mind-boggling discoveries led to the award of the 2006 Nobel Prize in physics to the leaders of the COBE team: Goddard's own John Mather, and George Smoot (University of California, Berkeley).

***Dr. Mather is the very first NASA scientist ever to win a Nobel Prize*, and we are enormously proud that all of his work was done right here at Goddard.**

What's the Matter?

The COBE mission's cosmic microwave background (CMB) radiation measurements gave scientists a lot to work with, but they needed more detailed pictures to understand better the temperature and density differences in the early Universe. In 2001 NASA launched the Wilkinson Microwave Anisotropy Probe (WMAP), built by Goddard in collaboration with Princeton University.

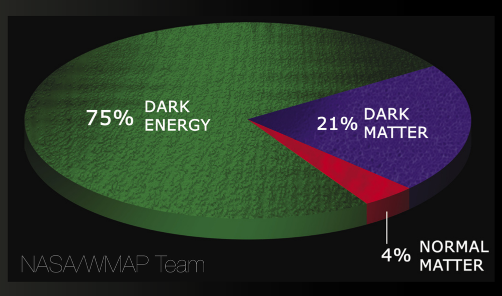


WMAP's all-sky temperature map shows more detail than the one produced by COBE.

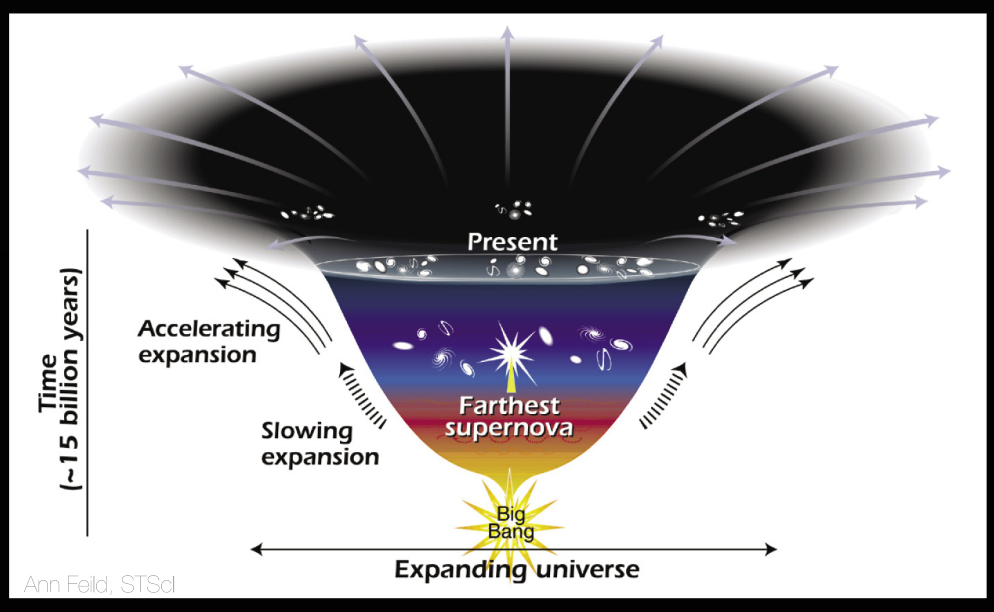
WMAP's data confirms that our Universe has expanded and cooled since the Big Bang, and that the early Universe was not perfectly uniform in density. It shows, with unprecedented detail, the areas with higher density which accumulated mass to form the first structures. These structures evolved to become galaxies, stars, and planets.

Combined data from WMAP and other missions tell us that the Universe is 13.7 billion years old. WMAP also revealed some drop-dead, can't-even-imagine-it information: we only know what makes up 4 percent of the Universe's contents. The other 96% is made up of exotic stuff called dark matter and dark energy. What is this mysterious "stuff"? That is one of the biggest questions in modern physics!

Did you know?



Only 4 percent of the Universe's contents are in the form of "normal" matter - what we find in stars, people and tulips!



The rate of expansion since the Universe's birth has changed over time. The shallower the curve, the faster the rate of expansion.

Data from the CMB further suggest that the first stars formed just a few hundred million years after the Big Bang. To observe them, astronomers need huge space telescopes – bigger than any in existence.

Goddard is working on that next big telescope. We currently lead development of the James Webb Space Telescope (JWST), with about nine times the collecting area of the Hubble Space Telescope. Scientists believe faint light from early stars was shifted into the cooler infrared wavelength by the expansion of the Universe, just as Big Bang energy was shifted to microwaves. So by detecting infrared light, JWST will give us a much clearer view of these youngsters.

NASA looks to the future with the "Beyond Einstein" program. One of the program's five exciting missions now in development is dedicated to studying the CMB in even greater detail.